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STUDY OF PROCESS PARAMETERS OF FRICTION STIR WELDED AA 7020 ALUMINUM ALLOY IN O AND T6 CONDITIONS

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Abstract (10pt)

This procedure utilizes a non-consumable device to create frictional warmth in AA 7020 T-6 the adjoining surfaces. The welding parameters and device stick profile assume significant parts in choosing the weld quality. In this examination, an endeavor has been made to comprehend the impact of hardware speed (rpm) and instrument stick profile on Friction Stir Processing (FSP) zone arrangement in aluminum compound. Grating blend welding between 7020 aluminum compound plates with a thickness of 6 mm was performed. Three distinctive instrument stick profiles (straight tube shaped, decreased round and hollow, triangular, square and cone) have been utilized to manufacture the joints at three diverse rotational rates i.e. 500, 1000 and 1500 rpm under a steady navigate speed of 0.43 mm/sec. The development of FSP zone has been broke down visibly. Hardness properties of the joints have been assessed and connected with the FSP zone development. From this examination it has been discovered that the device sticks profiled plans had little impact on warm info and tractable properties, weld properties were overwhelmed by warm information as opposed to the mechanical twisting by the instrument for the plate thickness of 6 mm. Decreased round and hollow stick profiled device delivers mechanically stable and metallurgical deformity free welds.

Keywords:

Friction Stir Welding;
7020 aluminum alloys;
Welding speed;
Axial force.

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1. Introduction

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AA 7020 T-6 Aluminum combination has the essential material in the manufacture of light weight structures requiring a high quality to weight proportion. Grating Stir Welding (FSW) is decently a current procedure that uses a non-consumable turning welding apparatus to create frictional warmth and plastic misshapening at the welding area while the material is in strong state. The primary points of interest are low twisting, nonappearance of dissolve related imperfections and high joint quality. Instrument plan and material assumes an imperative part notwithstanding the critical parameters like device rotational speed, welding speed and hub drive.

Joining of steels to aluminum combinations can be utilized for delivering steel/aluminum bimetallic parts in an extensive variety of mechanical regions. The contact blend butt and lap welding of steels to different aluminum composites have been contemplated. Nonetheless, it is hard to acquire a sound steel to aluminum joint by utilizing the ordinary combination welding forms because of the vast contrast between the liquefying purposes of steel and aluminum composites and furthermore the development of thick fragile Al/Fe intermetallic mixes at the joint interface. Contact Stir Welding is a strong state thermo-mechanical joining process (a mix of expelling and producing), developed by The Welding Institute (TWI) in 1991, that has turned into a reasonable assembling innovation of metallic sheet and plate materials for applications in different ventures, including plate materials for applications in different businesses, including aviation, car, resistance and shipbuilding.

As of late, numerical displaying of FSW has given noteworthy knowledge about the warmth age designs, materials stream fields, temperature profiles, lingering stress and mutilation, and certain parts of hardware plan. The improvement of new welding instrument materials and geometries has made it conceivable to join materials, for example, steel and titanium in the lab condition and in a set number of creation applications. In FSW, of steel it has been demonstrated that the lower welding temperature can prompt low mutilation and interesting joint properties. FSW of steel is a territory of dynamic research, so it is sensible to anticipate that other generation applications will develop after some time.

1.1. Friction Stir Welding (FSW) Process Principles

Friction stir welding (FSW) produces welds by utilizing a turning, non-consumable welding instrument to locally mellow a work piece, through warmth delivered by grating and plastic work, consequently enabling the device to "mix" the joint surfaces. The reliance on grinding and plastic work for the warmth source blocks noteworthy dissolving in the work piece, keeping away from a significant number of the challenges emerging from an adjustment in state, for example, changes in gas solvency and volumetric changes, which regularly torment combination welding forms.

Further, the decreased welding temperature makes conceivable drastically bring down twisting and lingering stresses, empowering enhanced weakness execution, new development methods, and making conceivable the welding of thin and thick materials.

1.2. Objectives

For this research work, the objectives that are tried to achieve by the researcher are:

a) To get optimum parameters for the materials under considerations i.e. alloy steel and Austenitic Stainless Steel.
b) To investigate the Heat Affected Zone (HAZ) and Thermo-Mechanical Affected Zone (TMAZ).
c) Defects occurring during the welding process.

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1.3. Scope of Study

The concentration of the examination work will be amassed in the mechanical execution and the blend zone microstructure by FSW lap and butt-welded part having 150mm × 100mm × 6mm thick sheet aluminum (AA 7020-T7) and 150mm × 100mm × 6mm thick sheet Austenitic Stainless Steel utilizing distinctive stick widths. All the testing of welded part will be tried by ASTM standard. Diverse stick distances across device will used to direct trials.

In this examination, Universal Testing Machine (UTM), Optical Microscope (OM) to get the microstructure properties and Scanning Electron Microscope (SEM) will likewise be utilized to quantify HAZ and TMAZ zone. Grinding mix welding (FSW) is a moderately new strong state joining process. This joining system is vitality proficient, condition cordial and flexible. Specifically, it can be utilized to join high-quality aviation aluminum compounds and other metallic composites that are difficult to weld by traditional combination welding.

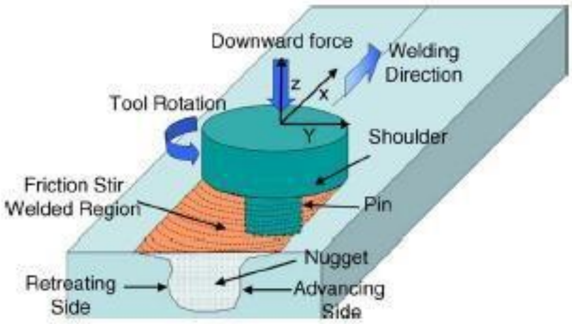


Figure 1. *JangerGotra I Mecaling*dance

FSW is thought to be the most noteworthy advancement in metal participating in 10 years. As of late, rubbing mix preparing (FSP) was created for microstructural change of metallic materials. Because of high erosion protection and remarkable mechanical properties and the reference stage outline of Al-Fe frameworks, Baker expresses that the low dissolvability of iron in aluminum advances the development of weak intermetallic mixes (IMCs, for example, Fe_2Al_5, $FeAl_3$ and FeAl, in the weld zone.

Specific accentuation has been given to (a) systems in charge of the arrangement of welds and microstructural refinement and (b) impacts of FSW/FSP parameters on resultant microstructure and last mechanical properties have been considered. The innovation dissemination has essentially outpaced the major comprehension of microstructural development and microstructure-property connections amongst metals and amalgams. In addition, the utilization of lightweight metals (for instance, Al composite) as the basic segments to supplant the heavier steel amalgam in car have been believed to be a promising methodology.

The joining, does not include any utilization of filler metal and along these lines any aluminum amalgam can be joined without worry for the similarity of piece, which is an issue in combination welding. Whenever alluring, different aluminum combinations and composites can be joined without any difficulty.

As opposed to the customary rubbing welding, which is typically performed on little axisymmetric parts that can be turned and pushed against each other to shape a joint, FSW can be connected to different sorts of joints like butt joints, lap joints, T butt joints and filet joints. The key advantages of FSW are condensed in Table: 1.

Table 1. Key benefits of friction stir welding.

Metallurgical benefits	Environmental benefits	Energy benefits
Solid Phase Processing	No shielding gas required	Improved materials use (e.g., joining different thickness) allows reduction in weight
Low distortion of work piece	No surface cleaning required	Only 2.5% of the energy needed for a laser weld
Good dimensional stability and repeatability	Eliminate grinding wastes	Decrease fuel consumption in light weight aircraft, automotive and ship applications
No loss of alloying elements	Eliminate solvents required for degreasing	
Excellent metallurgical properties in the joint area	No properties	
Fine microstructure	Consumable materials saving such as rugs, wire or any other gases	
Absence of cracking		
Replace multiple parts joined by fasteners		

Prior to the innovation of FSW, there had been some critical mechanical improvements of non–combination welding forms, which have discovered some constrained modern employments. A huge procedure of these is grating welding created at the time just before laser was imagined. Amid grinding welding, the pieces to be welded are compacted together and are made to more in respect to each other. In this manner frictional warmth is created to mellow the material in the joining area.

The last advance is made by applying expanded weight to the diminished material to yield a metallurgical joint without dissolving the joining material. Be that as it may, the relative development amid the phase of warmth age and material softening can basically just be rotational or direct. In spite of the fact that erosion welding operation is straightforward, the welding geometry is very confined and along these lines its utilization is likewise constrained.

For strong state welding, the thermo mechanical rule of contact welding had really laid an imperative base for the later development of FSW. The Welding Institute (TWI) in the UK had for quite a long time occupied with different R&D and modern exercises of grinding welding and surfacing. Wayne Thomas and his associates in TWI had since quite a while ago took a shot at and created rubbing expulsion, contact hydro pillar preparing and third-body erosion joining forms. To date it is with aluminum compounds that FSW is most effectively connected. The purpose behind the dominating utilization of FSW on aluminum composites is a mix of process straightforwardness on a fundamental level and the wide utilization of aluminum amalgams in many real businesses. It is particularly the situation where some aluminum composites are hard to combination weld as, is unmistakably clear in FSW application made by Boeing for influencing the Delta 2 to rocket tanks. FSW enabled them to significantly diminish their deformity rate to about zero. Most extreme temperature amid FSW can achieve just beneath the solidus of the work piece compound. For most aluminum combinations, it is altogether under 660 ºC. In this manner, A513 compound 1020 gentle steel or fast instrument steel, which is very economical, is an agreeable device material. Along these lines, FSW of aluminum compounds is generally direct, in spite of the fact that FS building, especially for parts and structures of high geometry unpredictability, can be very testing.

Grinding blend welded propelled high-quality steel (AHSS) joints are inadequate. Be that as it may, FSW and contact spot blend welding (FSSW) permit the likelihood of joining propelled high-quality steels and lessen issues related with protection spot welding (RSW). On a basic level, FSW could be connected for welding of all strong metallic materials. Amid FSW of steels, the nearby working temperature created by both grinding and twisting should be at 1100 ºC – 1200 ºC with the goal that the workpiece material is adequately plasticized for mixing and welding. Such high working temperatures and the important powers following up on the instrument amid FSW make an uncommon request on the mechanical properties of the device material.

These factors all demonstration to decide the result of the welding procedure. The welding procedure influences these joint properties basically through warmth age and scattering, so essential consideration ought to be given to the impact of the welding procedure factors on warm age and related results.

Table 2. Main FSW process variables

Tool design Variables	**Machine Variables**	**Other Variables**
Shoulder and pin materials	Welding speed	Anvil material
Shoulder diameter	Spindle speed	Anvil size
Pin diameter	Plunge force or depth	Work piece size
Pin length	Tool tilt angle	Work piece properties
Thread pitch		
Feature geometry		

2. Design Methodology

2.1. Tool Design

The FSW device Nomenclature utilized for the rubbing mix welding of AA 7020-T6 Aluminum combination and the manufactured FSW instrument for erosion mix welding of 6mm thick aluminum compound plates are appeared in the Figure.

For FSW of aluminum alloy plates, the tool material selected is SS 316 steel

Tool Steel and the tool dimensions used are:

D= 18mm
d = 5mm
L = 5.8mm

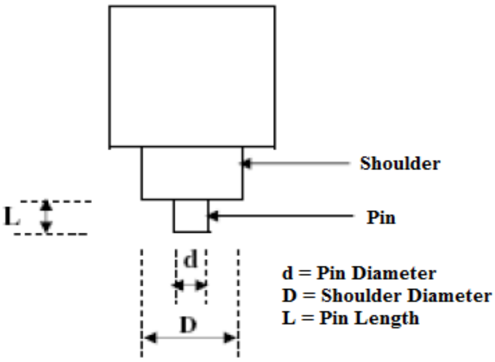


Figure 2. FSW Tool Nomenclature

2.2. Straight Cylindrical Pin

The FSW apparatus with tube shaped stick profile to weld 5mm thick aluminum AA7020 T6 plates is appeared in cry fig. The stick for this device has a straight round and hollow shape with a tube-shaped shoulder.

Figure 3. Straight cylindrical pin profiled tool

2.3. Manufacturing of Tools

The device material was purchased as delicate tempered bars of measurement 40 mm. In view of the device biggest shoulder plan; bar width required was 20 mm. A material list was available with the material including its history, mechanical properties, and warmth treatment conditions. All the machining operations were performed utilizing machine and processing machine. No exceptional instruments are utilized aside from the screwing of the stick.

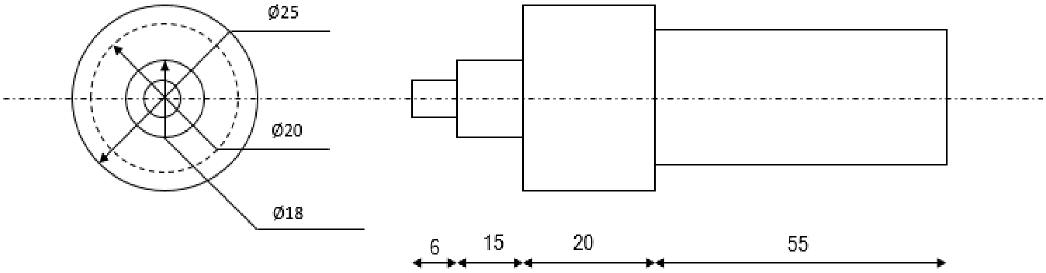
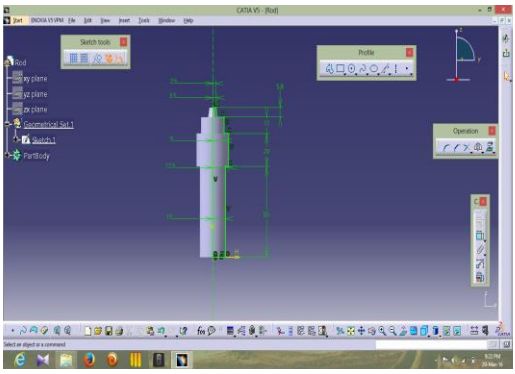


Figure 4. Final shape of the pin by machining operation



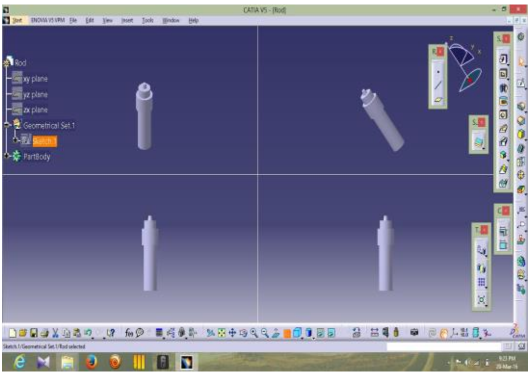


Figure 5. Catia model (Front view)

Figure 6. Catia model (Multi sectional view)

Figure 7. Different types of tools

Table 3. Nominal Chemical Composition of tool material

Element	**Carbon**	**Chromium**	**Nickel**	**Manganese**	**Silicon**	**Phosphorus**	**Sulfur**	**Molybdenum**	**Fe (Iron)**
wt (%)	0.04	017-19.5	11-15	3	2	0.055	0.04	3-4	Balance

Table 4. Mechanical Property

Ultimate Tensile Strength (Mpa)	**Yield Strength (Mpa)**	**Elongation (mm)**	**Rockwell hardness**	**Thermal conductivity (W/mk)**	**Melting point (K)**	**Poisson Ratio**	**Specific heat (J/KgK)**	**Poisson's Ratio**
620	290	50%	79	17	1673	0.275	530	0.275

3. Experimental System

A spiral penetrating machine or outspread arm press is an outfitted bore head that is mounted on an arm get together that can be moved around to the degree of its arm reach. The most essential segments are the arm, section, and the penetrate head. The bore leader of the outspread penetrating machine can be moved, balanced in stature, and turned. Beside its reduced plan, the spiral bore press is fit for situating its bore make a beeline for the work piece through this outspread arm component.

This is most likely one reason why more mechanics lean toward utilizing this sort of penetrating machine. Truth be told, the outspread boring machine is viewed as the most flexible kind of bore press. The undertakings that an outspread boring machine can do incorporate drilling gaps, countersinking, and granulating off little particles in stone work works.

Specification: -

Speed range: - 500-1500 rpm
Spindle motor: -5.5 KW

Figure 8. Experimental setup

3.1. Workpiece material

The work piece material is AA7020-T6 category.

Table 5. Chemical composition of workpiece.

Aluminium	**Copper**	**Magnesium**	**Silicon**	**Ferrous**	**Mn**	**Ni**	**Zn**	**Zr**	**Ti**	**Cr**
91.4	0.17	1-1.5	0.325	0.4	0.45	0.0	4-5	0.20	0.17	0.35

Table 6. Mechanical properties

Thermal conductivity (w/mK)	**Thermal diffusivity**	**Thermal expansion (µm/mK)**	**Specific heat capacity(j/KgK)**	**Melting point (K)**	**Shear modulus (GPa)**	**Tensile strength (GPa)**
140	58	23.3	870	873	26	0.390

3.2. Finding the working limits of parameters

A large number of trial runs were carried out using 6mm thick weld plates of AA 7020-T6 aluminum alloy to find out the feasible working limits of FSW process parameters. Different combinations of process parameters were used to carry out the trial runs. This was carried out by varying one of the factors while keeping the rest of them at constant values. The working range of each process parameter was decided upon by inspecting the macrostructure (cross section of the weld) for a smooth appearance without any visible defects such as tunnel defect, pinhole, etc. From the above inspection, the following observations have been made: When the tool rotational speed was lower than 500 rpm, worm hole at the retreating side of weld nugget was observed (Figure 9) and it may be due to insufficient heat generation and insufficient metal transportation, when the rotational speed was higher than 1000 rpm, crack defect was observed (Figure 10) and it may be due to less generation of heat.

Similarly, when the welding speed was 0.43mm/sec and rotational speed 1500rpm, the weld quality was good which was observed in (Figure 11).


Figure 9. At 500 rpm


Figure 10. At 1000 rpm


Figure 11. At 1500 rpm

Hence the range of process parameter such as tool rotational speed was selected as 1500 rpm, the traverse speed was selected as 0.43 mm/sec. The FSW process parameters along with their ranges are given in the table.

Table 7. Process parameter with their ranges and values at three levels

Level	**Rotational speed N(RPM)**	**Traverse speed, S(mm/sec)**
Range	500-1500	0.43
Level 1	500	0.43
Level 2	1000	0.43
Level 3	1500	0.43

Device pivot speed variety is in charge of the power applied on the component. At the point when the device pivot speed increments, higher power will be included and accordingly the entrance of the apparatus material will be simpler. What's more, the instrument turn speed is in charge of the blending rate of the material. Welding velocity (or) material sustain rate variety is in charge of the measure of warmth and the protection of the work piece to be welded. Moderate encourage rates think the warmth inside the component making coarser grain sizes. The warmth included will increment in light of the fact that the instrument will be subjected to bigger time in contact with the work piece while turning which creates more warmth. Higher nourish rates will oppose the movement of the apparatus between the sheets. In any case, less warmth will be engaged with the component. In this way, Tool pivot speed, welding speed and hub compel are in charge of the great nature of welds, mechanical properties, and microstructure of the weld.

3.2. Analysis of microstructure

The SS-316 instrument steel with barrel stick and curved shoulder of 3° was utilized to expand the stream of combinations. Utilizing transformation of 500 rpm and bolster of 0.43 mm/sec didn't give great properties regardless of development of onion rings and stream lines as a result of wrong conditions; additionally, the warmth influenced zone (HAZ) has comparative grain size and circulation to the base metal (amalgam). While utilizing an upset of1000 rpm for this instrument prompt an imperfection named "kissing bond" which is a passageway of oxygen to frame high thickness Al2O3 with an undefined structure. It was discovered that expanding of hardware insurgency to 1100 rpm upgrades the mechanical properties as appeared in test (B3) which gives the best properties for this situation. While the pivot velocities of 1500 rpm decreases the mechanical properties as in test (B4). The three weld zones were outlined in the photos.

Figure 12. Macrograph of cross section of welded sample.

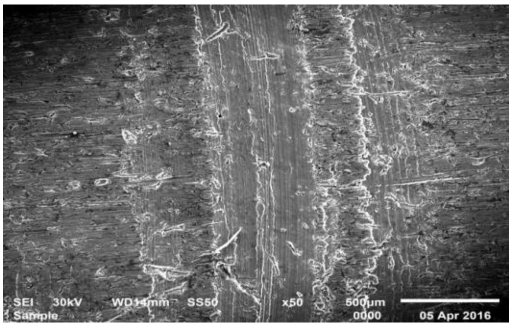


Figure 13. Onion ring like structure

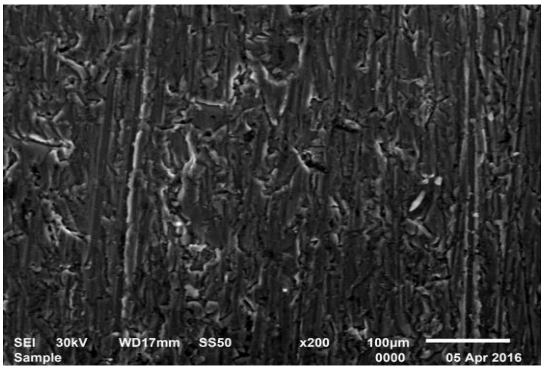


Figure 14. Changes in grain of base material

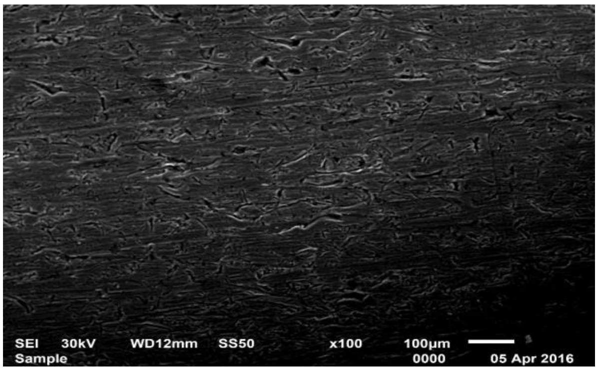


Figure 15. Changes in grain of welded material

3.4. Rockwell hardness test

By using all the procedure and taking 100Kgf load and 1/16” Steel ball Indenter we found that the hardness of base metal is B87 and B89 in weld bead region.

Table 8. Specification of hardness machine

Capacity	60Kgf, 100Kgf, 150Kgf
Steel ball Indenter	1/16”
Test Blocks	3 Nos

Figure 16. Base Metal Hardness is B87

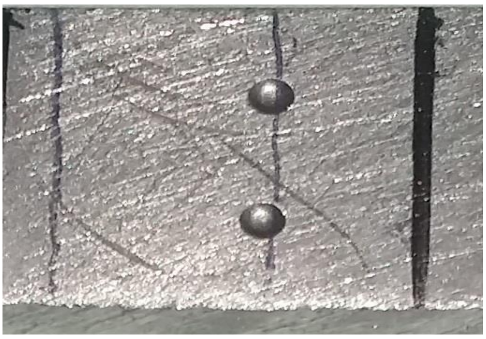


Figure17. Weld bead Hardness is B89

3.5. Drill tool dynamometer

Drill Tool Dynamometers that are used for measurement of both the thrust force of the control and the torque, which is produced on the work piece. In addition to this, these are also used to establish study tool configuration, drilling force and lubricant characteristics.

During the operation we have found that: -

1. Thrust force= 713 Kgf
2. Torque= 106Kgm

Figure 18. Drill tool Dynamometer

4. Result and Discussion

The welding cross speed (v), the instrument rotational speed (ω), the descending power (F), the tilt edge of the device and the apparatus configuration are the fundamental factors normally used to control the FSW procedure. The pivot of the apparatus brings about blending of material around the device test while the interpretation of the device moves the mixed material from the front to the back of the test. Hub weight on the instrument additionally influences the nature of the weld. It implies that high weights prompt overheating and diminishing of the joint, while low weights prompt lacking warming and voids. The tilt edge of the instrument, measured as for the work piece surface, is additionally an essential parameter, particularly to assist creating welds with "smooth" apparatus shoulders.

As said some time recently, instrument configuration impacts warm age, plastic stream, the power required to perform FSW and the consistency of the welded joint. For the most part, two device surfaces are expected to play out the warming and joining forms in FSW. The shoulder surface is where most of the warmth by rubbing is created. This is substantial for moderately thin plates; generally, the test surface is where most of the warmth is produced. For this situation, the cone shaped apparatus bear builds up a weight under the shoulder, yet additionally works as an escape volume for the material dislodged by the test because of the dive activity. As the test tip must not enter the work piece or harm the support plate, in all instrument outlines the test tallness is constrained by the work piece thickness. So, by taking every one of the parameters into the record we have figured the warmth produced from the three surfaces of the device.

Calculated data: -

1. Length of the work piece (L) =150mm.
2. Time taken to travel (bed movement of 150mm) =310sec.
3. Welding speed (S) =150/310 mm/sec
4. Current supply (I) =14.1 Amp
5. Voltage supply (V) = 240V
6. Width of weld bead (W) =18 mm
7. Length of weld bead (L1) = 150mm
8. Area of weld bead (Ab) =150 X 18 mm2
9. Torque =106 Kgm
10. Force = 713 Kgf

4.1. Heat generation from the shoulder

The shoulder surface of a cutting edge FSW apparatus is as a rule curved or narrowly molded. Past explanatory articulations for warm age incorporate a level roundabout shoulder, at times excluding the commitment from the test.

Heat generation from the Shoulder $Q1 = \frac{2}{3}\pi\tau\omega\,(Rs^3\text{-}Rp^3)\,(1+\tan\alpha) = 42992.16$ watt

4.2. Heat Generation from the Probe

The heat generated at the probe has two contributions: Q_2 and Q_3 from surfaces.

$Q2 = \frac{2}{3}\,\pi\tau\omega Rp^2\ XHp = 2182.64$ watt

$Q3 = \frac{2}{3}\,\pi\omega\tau Rp^3 = 940.795$ watt

Total Hear Generation Q = Q1+Q2+Q3 = 46.115 KW

4. Conclusion

Mechanical properties of FSW welded aluminum combination AA 7020-T6 change with changing of process parameters. Rigidity of FSW welds is specifically corresponding to the travel/welding speed. Hardness brought was seen up in the weld district. That softening was most obvious in the warmth influenced zone on the propelling side of the welds that compared to the disappointment area in elastic tests.

- A starting phase of a passage deformity was found at the crossing point of weld chunk and canteen mechanically influenced zone.
- When the instrument rotational speed was lower than 500 rpm, worm opening at the withdrawing side of weld chunk was watched.
- When the rotational speed was higher than 1000 rpm, break deformity was watched.
- When the welding speed was 0.43mm/sec and rotational speed 1500rpm, the weld quality was great as for past levels.

By utilizing Scanning Electron Microscope, we found that diverse sort of microstructure in the weld dot locale, amid the examination we found that the Rockwell hardness is expanded in weld dot district.

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